

sediment deposition at a rate about ten times faster than pre-cultural conditions (Engstrom and Almendinger, 1998).

Chlorophyll *a*

Chlorophyll *a* is a major plant pigment that provides an index of algae biomass and a means to assess eutrophication. The chlorophyll measurements presented here are corrected for pheophytin and thereby represent the chlorophyll *a* contribution provided by “living” algae only. This pigment is derived from a diverse phytoplankton community typical of a riverine system, including diatoms and other chrysophytes, green algae, and cyanobacteria (blue-green “algae”). In general, chlorophyll concentrations increase with nutrient enrichment in lakes, reservoirs and slow moving rivers typical of the navigational pools and backwaters of the UMR. Chlorophyll concentrations greater than 30 ug/L usually present a visible “bloom” and may be objectionable by many users. The states have not established and adopted chlorophyll criteria or water quality standards for the river.

Chlorophyll measurements for the UMR were not commonly made by all agencies, especially during the 1980s. However, the available data indicate high chlorophyll concentrations are found throughout the UMR (Figure 39) and reflect an abundance of nutrients, especially dissolved forms of phosphorous, nitrogen and silica that are important for riverine algae. Regression analysis revealed chlorophyll levels are usually highest during periods of low to moderate flow and lowest during high flow conditions. Reduced mixing and increased hydraulic retention time during low flows likely favors phytoplankton growth, whereas high flows reflect turbulent conditions when light availability is lower and increased flushing is less favorable to phytoplankton development.

Maximum chlorophyll levels exceeded 100 ug/L at many sites during the 1990 to 1994 monitoring period. Chlorophyll concentrations were notably less during the 1995 to 1999 periods (Figures 40 and 41) and did not appear to be flow-related. It is suspected that zebra mussel filter feeding may have contributed to this decline in the late 1990s when water quality-induced impacts began to be reported for portions of the UMR (Sullivan and Endris, 1998).

Fish Contaminant Data

As was apparent with the water quality data, fish contaminant information was not equally distributed throughout the Upper Mississippi River (Figures 42 and 43). Polychlorinated biphenyls (PCBs), chlordane, and mercury were the contaminants most frequently monitored. The Wisconsin Department of Natural Resources has obtained the

**Figure 39 - Total Chlorophyll a Concentrations in the Upper Mississippi River
Summer Data Collected over Four Time Periods**

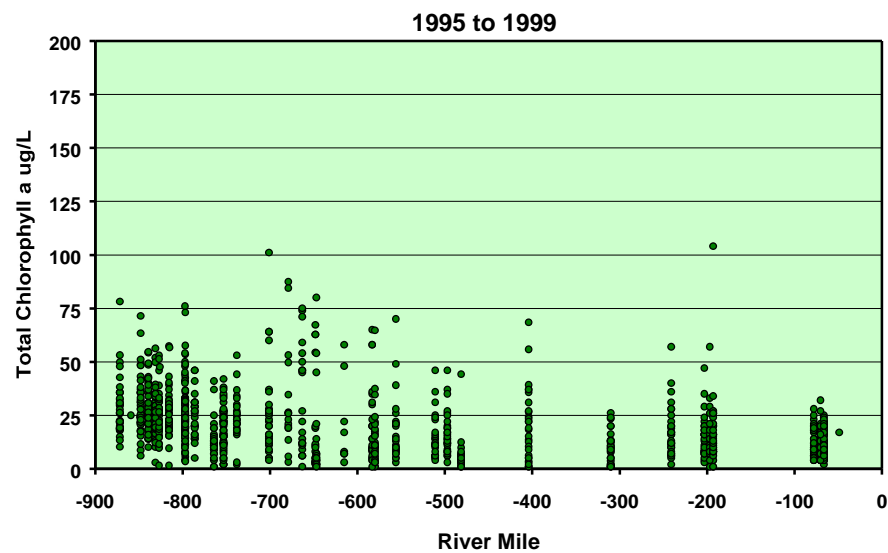
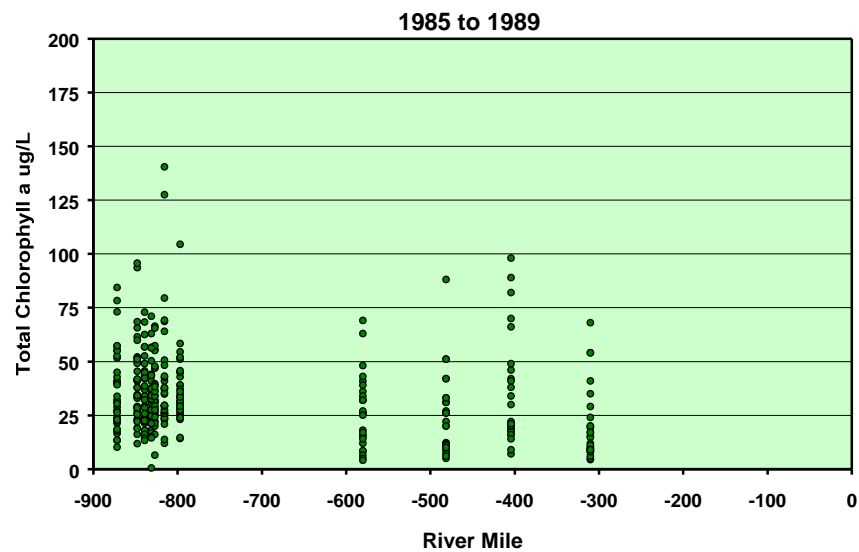
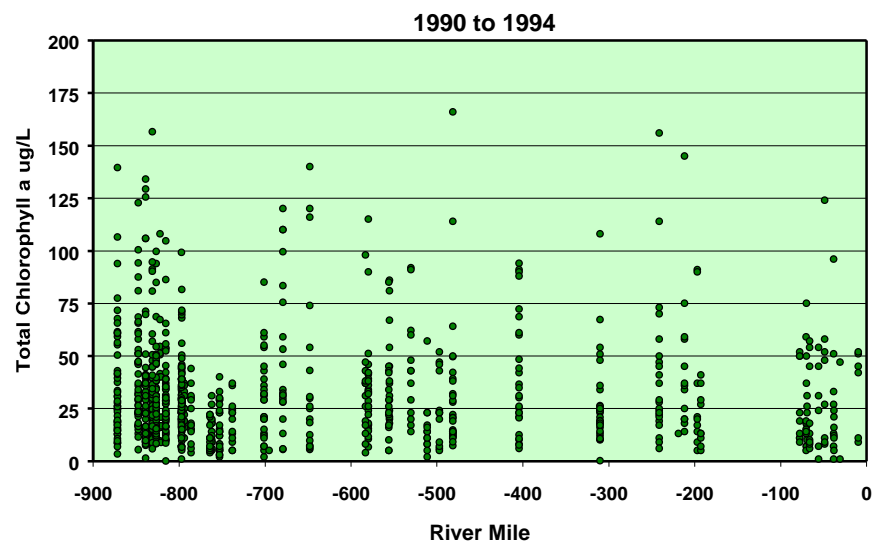
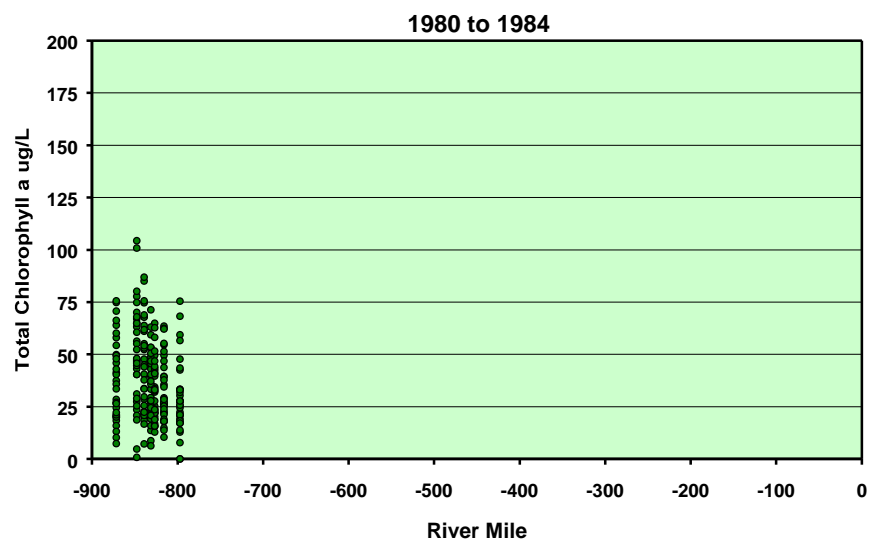
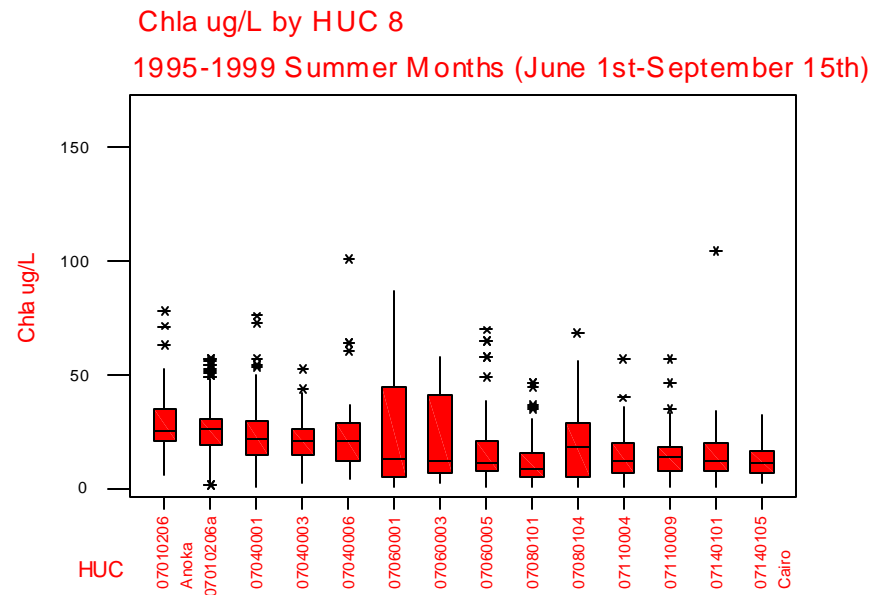
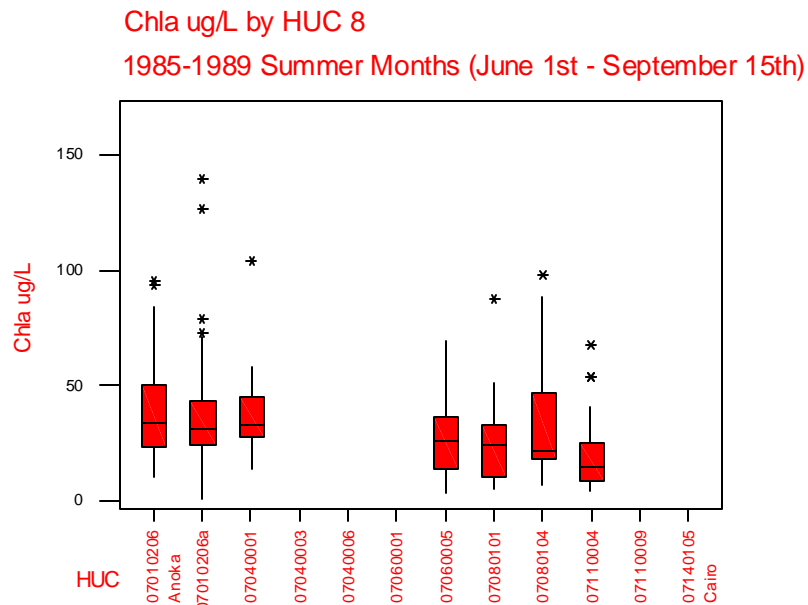
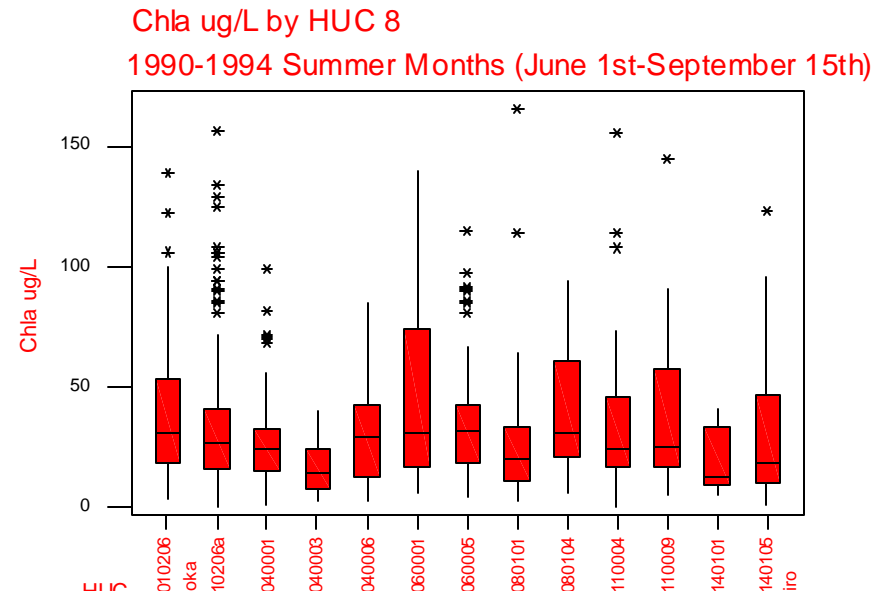
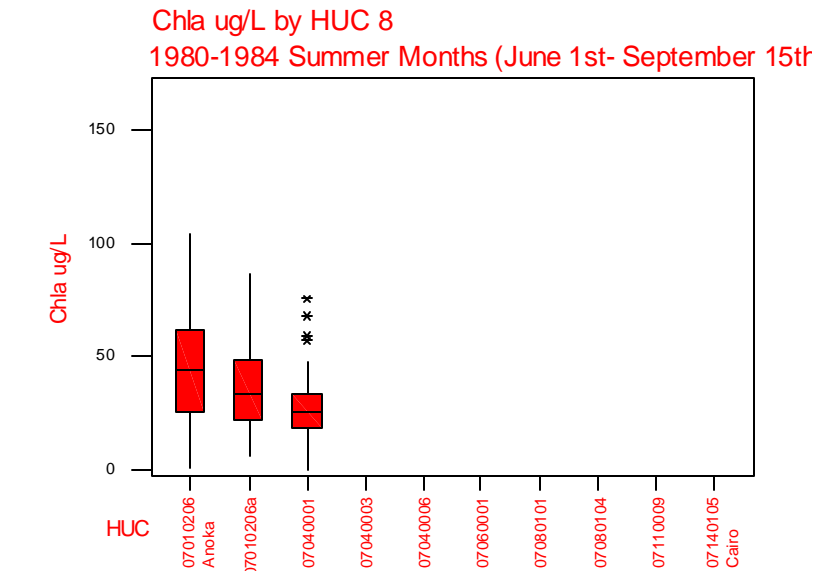
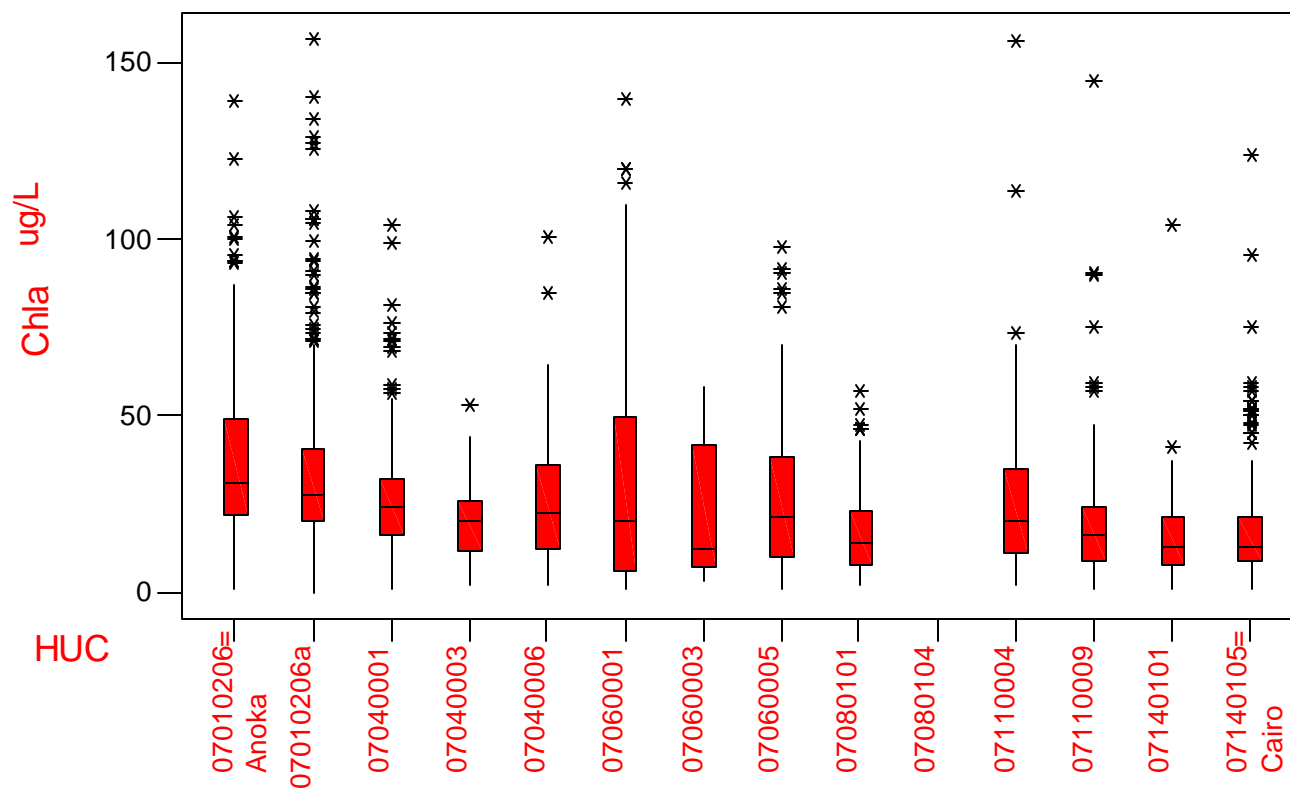


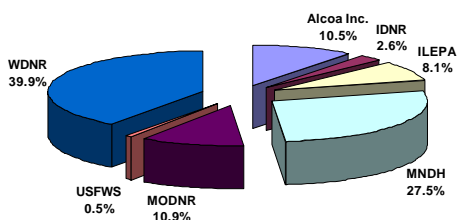
Figure 40: Boxplots of Total Chlorophyll a Data by HUC over four time periods



1980-1999 Summer Months (June 1st to September 15th) Boxplots of Chla by HUC



All Samples N = 3647



Fillet Samples N = 2958

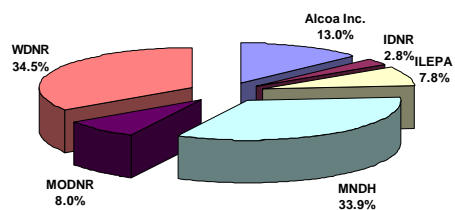


Figure 42. Sources of fish contaminant data for the Upper Mississippi River. Abbreviations: IDNR= Iowa Department of Natural Resources, IEPA = Illinois Environmental Protection Agency, MNDH = Minnesota Department of Health, MODNR = Missouri Department of Natural Resources, USFWS = U.S. Fish and Wildlife Service, WDNR = Wisconsin Department of Natural Resources.

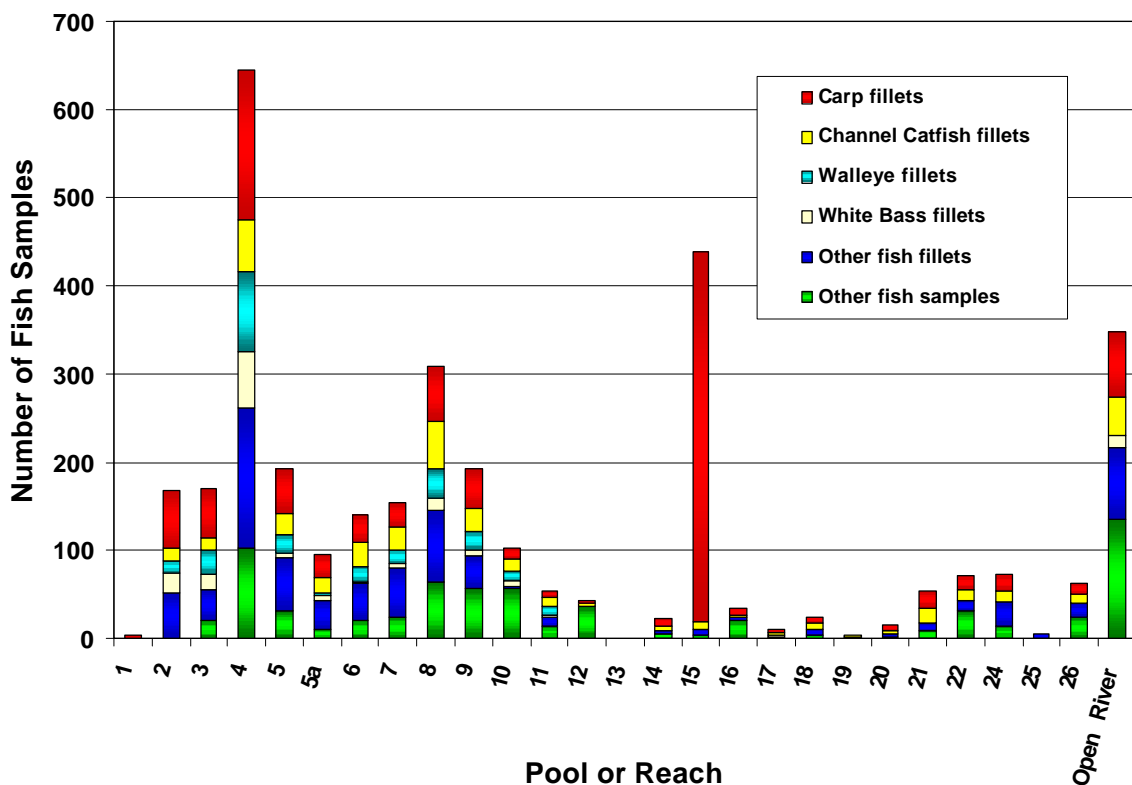


Figure 43. Total numbers of fish contaminant samples and major species of fish fillets collected from the navigation pools and open river reach of the Upper Mississippi River.

most samples, comprising 39.9 % of the total database. This was followed by the Minnesota Department of Health and the data compiled for Missouri by the Missouri Department of Natural Resources, which accounted for 27.5 and 10.9%, respectively of the data. The Missouri fish contaminant data was a compilation of data from 14 state and federal agencies, with the principal source being the Missouri Department of Conservation. Alcoa's carp data for Pool 15 represented 10.5 % of the samples. The remaining three sources combined, Illinois, Iowa, and the U.S. Fish and Wildlife Service, accounted for 11.2% of the fish contaminant data. A total of 3,719 fish samples was compiled from these sources, including samples from Minneapolis, MN to Memphis, Tennessee. For the purpose of this report, samples from below the Ohio River confluence were omitted, thus reducing the total number of samples to 3,647. The types of fish tissue analyzed by the reporting agencies included whole fish, fillets, and eggs. Of these fish tissue types, skin-on and skin-off fillets accounted for almost 3000 samples, representing about 80% of the data (Figures 42 and 43). For the purpose of this evaluation, no distinction was made between skin-on and skin-off fillets. Fish samples represented tissue analyzed from either a single fish or a composite of several fish (same species) that were approximately the same length.

Inconsistent reporting of field data by the monitoring agencies resulted in missing information. In some cases, the date (month and day) and sampling site information (i.e. river mile and habitat type) were not provided. However, since the primary objective is to assess broad system-wide trends over approximately 20 years, the need for specific site and collection information was not critical. Missing data on the size or weight of the fish sampled posed an additional problem. The size (age) of fish is an important factor for evaluating contaminant data, since chlorinated organic compounds and mercury accumulate over time. The species of fish is also an important consideration for evaluating fish contaminant data. Many species prefer certain habitats that provide different levels of contaminant exposure or prey on food items with varying contaminant body burdens. The lipid content of the fish is also a critical factor affecting PCBs and chlordane bioaccumulation, since these compounds are nonpolar and have a strong tendency to accumulate in fatty tissue.

In order to provide some control over the above considerations related to fish contaminant data, the evaluation of the longitudinal distribution of PCBs, chlordane, and mercury in UMR fish was limited to, the data obtained from fillet samples of specific species of fish. The carp was the most frequently sampled fish, and because of its relatively high lipid content, it serves as a good target organism for assessing PCB and chlordane contamination. Other frequently sampled fish with a high lipid content included the channel catfish and white bass. The walleye was a commonly monitored sport fish in the upper river and was frequently tested for PCBs and mercury.

Polychlorinated Biphenyls - PCBs

Polychlorinated biphenyls (PCBs) represent a mixture of chlorinated biphenyl compounds with varying chlorine content. Beginning in the 1930s, PCBs were widely used in electrical equipment, lubricants, heat transfer agents, and other products. Because PCBs had become increasingly present in environmental samples and were posing health threats for humans and wildlife, Federal regulations were enacted in 1977 to greatly restrict PCB production and use. PCBs have been detected in various environmental samples from the Upper Mississippi River for more than 30 years, and PCB inputs have generally been associated with diffuse sources from the Twin Cities Metropolitan Area (Sullivan, 1998). To reduce human PCB exposure, all UMR states issue consumption advisories for sport fish obtained from the river.

Median PCB concentrations in carp fillets indicate that the highest PCB levels occurred in the upper portion of the study area during the 1980-1984 period (Figure 44).

Unfortunately, no data were available to assess PCB concentrations below Pool 12 during this period. Data collected during the 1985-1989 period were available river-wide and indicate a bimodal PCB distribution, with the greatest levels evident below the Twin Cities Metropolitan Area (Pools 2-4) and in the Quad Cities area (Pool 15). Carp samples obtained during the 1990s indicate a substantial reduction in PCB levels since the 1980s, especially in samples collected within the St. Paul to Lake Pepin reach (Pools 2 - 4). It should be noted that the PCB information for Pool 15 includes a large number of carp samples collected in an area influenced by a local PCB source (Alcoa, Incorporated) and does not reflect pool-wide conditions. PCB cleanup activities at the contaminated site in the mid-90s have resulted in notably reduced PCB concentrations in carp fillets from this area. Recent (1995-98) PCB concentrations in carp from Pools 13-14 appear to be higher than in other reaches of the river; however, these concentrations are based on only 3 samples collected from Pool 14 during this period, and may not be representative of the entire reach.

Over a 24-year period (1975-1998), Wisconsin has intensively monitored PCB concentrations in a number of fish species collected from Pools 3 and 4. An evaluation of these fish fillet data clearly shows higher PCB concentrations in channel catfish, carp and white bass as compared to walleye and bluegill (Figure 45). These inter-species differences are most pronounced in the fish collections from the late 1970s and early 1980s, before the widespread control of PCB inputs reduced environmental exposure. The lipid content of channel catfish, carp, and white bass is greater than that of walleye and bluegill, and is an important factor influencing the inter-species differences in PCB concentrations.

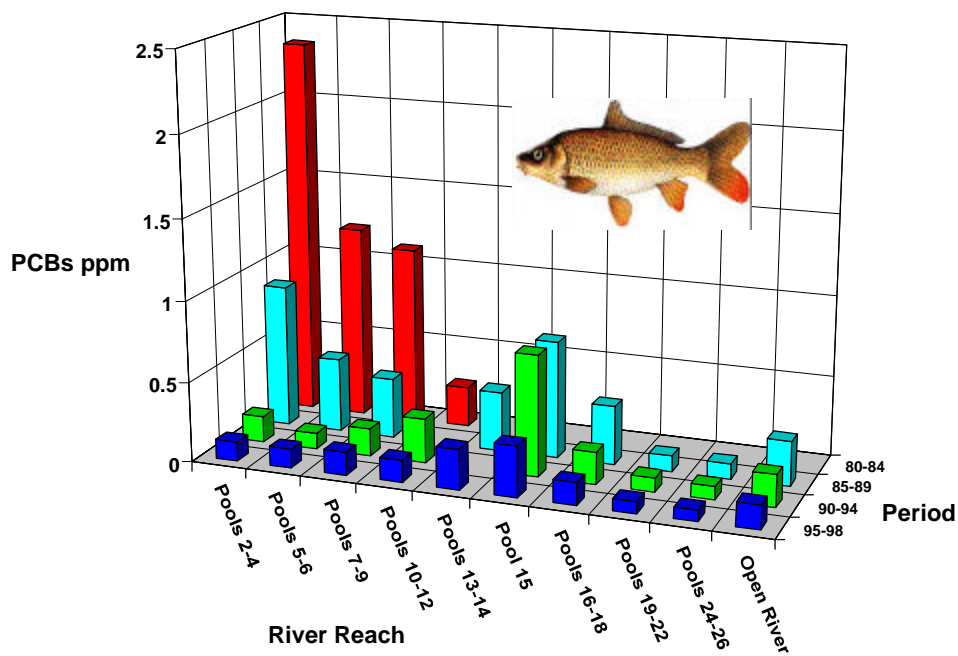


Figure 44. Median polychlorinated biphenyl (PCBs) concentrations in carp fillets from the Upper Mississippi River (1980-98).

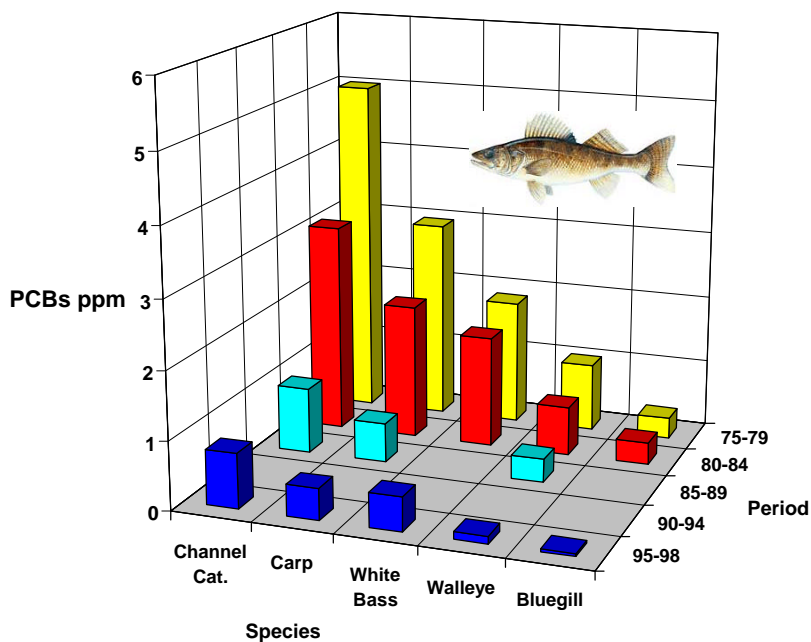


Figure 45. Median PCB concentrations in fillets of different fish species collected from Pools 3 and 4 of the Upper Mississippi River by the Wisconsin Department of Natural Resources (1975-98).

Chlordane

Chlordane is a pesticide that was manufactured between 1948 and 1988 and commonly used for the control of termites and corn crop pests. Chlordane is a mixture of many chemicals that add complexity to its analysis and reporting. Because of this complexity, total chlordane concentrations in fish tissue may have been determined using different methodologies, depending on the monitoring agency involved. These concentrations may reflect the sum of a number of specific analytes normally associated with chlordane, including cis-chlordane, trans-chlordane, oxychlorodane, cis-nonachlor, trans-nonachlor, heptachlor, heptachlor epoxide, and other compounds. Alternatively, an analysis of total chlordane may have been based on a technical chlordane standard containing mixtures of these components. These differences in analytical methods and reporting will yield different values for total chlordane. As a result, the chlordane data presented here are not strictly comparable and should be interpreted with caution. For more information on the chlordane data provided in this summary or in the compiled database, the reader is encouraged to contact the agency or laboratory that provided the information. The EPA began restricting chlordane's use in 1983 and banned its use in 1988, as a result of human health concerns and harm to the environment. Chlordane-based fish consumption advisories have been issued in the lower portion of the UMR, where this pesticide was more commonly used.

Chlordane concentrations in carp fillets are highest in the lower portion of the UMR (Figure 46). The highest median concentrations of approximately 0.25 ppm was apparent in the open river reach during the early 1980s. In contrast, chlordane concentrations in the upper portion of the UMR during the same time period were near or below detection levels (generally about 0.05 ppm). These spatial differences are likely associated with a more widespread use of chlordane in states bordering the lower river. As was noted for PCBs, there appears to be a reduction in chlordane contamination in carp fillets over the twenty-year period that probably reflects chlordane use restrictions and decreased inputs.

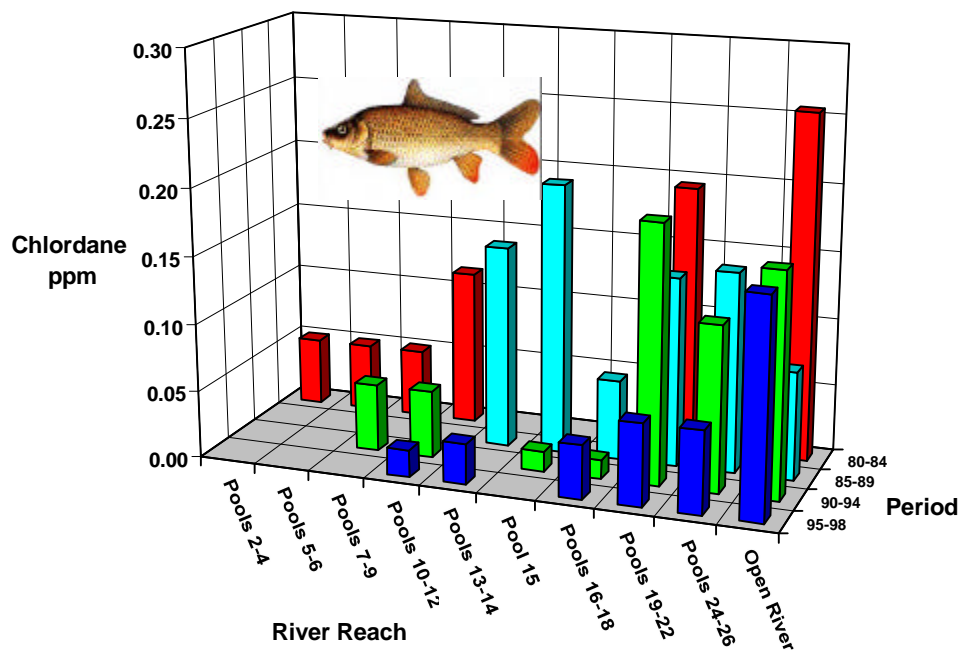


Figure 46. Median chlordanes concentrations in carp fillets from the Upper Mississippi River (1980-98).

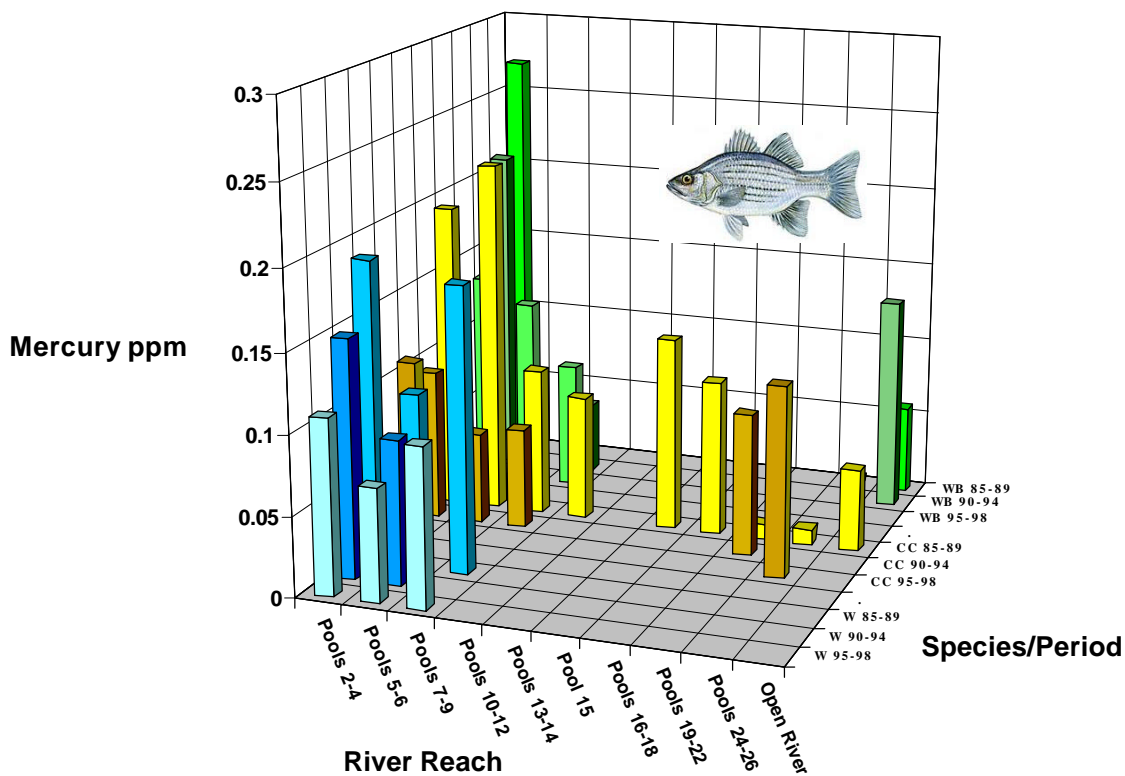


Figure 47. Median mercury concentrations in walleye (W), channel catfish (CC) and white bass (WB) fillets from the Upper Mississippi River (1985-1998).

Mercury

Mercury is a naturally occurring metal that may be present in environmental samples as elemental (metallic), inorganic, and organic forms. Methylmercury is especially important since it is the primary form that accumulates in tissues, thereby posing the greatest risk to wildlife and human health. Major anthropogenic sources of mercury include the burning of fossil fuels, mining activities, waste incineration, industrial and municipal point source discharges, and other releases from products containing mercury. For the past several years, some states have been issuing mercury-based fish consumption advisories for mercury for portions of the UMR. In 2001, the U.S. Food and Drug Administration and U.S. EPA jointly announced national consumption advice for consumers of marine and freshwater fish, to reduce the risk of mercury exposure to pregnant women, women of childbearing age, and young children.

The mercury data compiled for this evaluation are based on the analysis of total mercury in fish fillets. Of the 2958 fish fillet samples in the UMR database, 734 samples (25%) were analyzed for mercury. A majority of these samples were obtained in the upper portion of the UMR, where mercury-based fish consumption advisories have existed for a longer period of time. Almost two-thirds of the fillet samples for mercury were obtained from four fish species, including carp, channel catfish, walleye, and white bass. Carp were not included in this evaluation because they exhibited lower mercury concentrations than the other three species. Further, data prior to 1985 were not considered because few samples were available.

A longitudinal evaluation of mercury concentrations in the selected fish was difficult due to inadequate spatial sampling (Figure 47). Based upon the available data for channel catfish and white bass, the upper portion of the river (Pools 2 to 6) exhibited higher median mercury concentrations than the lower river (below Pool 14). The average mercury concentration in UMR channel catfish fillets was 0.12 ppm (all sites and 1985-1998 time period), slightly higher than the national average (0.09 ppm) reported for this species in a 1987 study by EPA (Bahnick et al. 1994). This same study reported a national average mercury concentration of 0.52 ppm in walleye fillets, which was noticeably greater than that found in walleye fillets from the UMR (0.18 ppm), using data from the present evaluation. In general, median mercury concentrations in fish fillets from the UMR appear to be showing a decreasing temporal trend during the 1985-1998 period, especially in walleye samples collected from Pools 2-9. This decreasing trend is consistent with the results of recent core studies of Lake Pepin sediments, which reveal declining mercury inputs over the last 30 to 40 years (Balogh et al. 1999). The authors believe point source mercury load reductions from industrial and municipal sources in the Twin Cities Metropolitan Area are a major factor responsible for these decreasing trends.